

Rensselaer Polytechnic Institute
Department of Electrical, Computer, and Systems Engineering
Fall 2002
ECSE 6961: Advanced Topics in Digital Signal Processing

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COURSE OBJECTIVE: This course is for graduate students who have already taken a course in basic digital signal processing and are looking to expand and integrate their understanding. The goal is to equip you with a toolbox of advanced techniques you can apply to signal and image processing problems in resource-constrained or probabilistic settings.

LECTURES: Tuesdays and Fridays, 3:30-4:50 PM, DCC 235.

PREREQUISITES: You should have already taken undergraduate-level courses in linear algebra (MATH-4100), probability (ECSE-4500), discrete-time linear systems (ECSE-4510), and digital signal processing (ECSE-6620). You should also be comfortable with Matlab programming.

WEBSITE: Assignments and other course material will be available through this WebCT page: http://webct.rpi.edu/public/ECSE_6961_01_0209. It is expected that you will check this page often to keep current on important information, to post questions, and to respond to others' questions. The WebCT bulletin board is the preferred means of asking a simple question, since I will check for and respond to questions frequently, and not duplicate effort answering similar questions from several different people.

GRADING: The final grade will be determined by homework and programming assignments (50%) and a larger final project (50%).

Homework will be assigned every week or two, and will be a mix of paper-and-pencil analysis and Matlab implementation. All homework should be done and written up on your own; general discussion of difficult problems with classmates is OK, but working out entire problems together is prohibited. Homework is due at the start of class on the date indicated. Homework loses 20 points on the first late day, 30 points on the second late day, and 50 points on the third late day, i.e. after 3 days you might as well not turn it in.

The final design project will be an integrated system that incorporates some of the tools discussed in the class. The projects should be done in *groups of two*. The scope of the project should be about four to six weeks' worth of effort. The project will include both written (70%) and oral (30%) components. The written part should include your goals, project background, the data and software you worked with, your algorithms and design, results, discussion, and references. The oral part will be scheduled during final exams and will consist of a 20 minute Powerpoint presentation and demonstration. More details on the project and suggestions for possible projects will be given towards the middle of the term.

TEXTS: These two texts are required:

- John G. Proakis et al. *Algorithms for Statistical Signal Processing*, Prentice-Hall, 2002.
- C. Sidney Burrus, Ramesh A. Gopinath, and Haitao Guo. *Introduction to Wavelets and Wavelet Transforms: A Primer*, Prentice-Hall, 1998.

SUPPLEMENTAL READING: These books may also be useful:

- A. Oppenheim, R. Schaffer, and J. Buck, *Discrete-Time Signal Processing*, 2nd Edition, Prentice-Hall, 1999. This standard text is available at the bookstore, if you don't have it from your previous DSP class. You don't need to buy it, though I will refer to it at several points.

There are a few other reasonable introductory DSP books:

- Sanjit K. Mitra, *Digital Signal Processing: A Computer-Based Approach*, McGraw Hill, 2001.
- Boaz Porat, *A Course in Digital Signal Processing*, John Wiley and Sons, 1997.

I may make some handouts from these books:

- Thomas W. Parks and C. Sidney Burrus, *Digital Filter Design*, John Wiley and Sons, 1987. Out of print.
- Richard E. Blahut, *Fast Algorithms for Digital Signal Processing*, Addison-Wesley, 1985. Out of print. RPI's library has a copy, but I have it checked out.
- Simon S. Haykin, *Adaptive Filter Theory*, 3rd edition, Prentice Hall, 1995. This is a standard reference on adaptive filtering, but I don't really like the development in some areas.

For wavelet references, you might consider:

- Ingrid Daubechies, *Ten Lectures on Wavelets*, SIAM Press, 1992. The classical reference on wavelets.
- Albert Boggess and Francis J. Narcowich, *A First Course in Wavelets with Fourier Analysis*, Prentice Hall, 2001. A very nice, somewhat mathematical introductory book on wavelets.

- Gilbert Strang and Truong Nguyen, *Wavelets and Filter Banks* Wellesley Cambridge Press, 1996. This book emphasizes the connection between wavelets and perfect reconstruction filter banks, but overall I think it's somewhat poorly written and organized- I wouldn't recommend buying it.
- Stéphane Mallat, *A Wavelet Tour of Signal Processing*, Academic Press, 1998. Often-referenced, but now out of print.

TOPICS: We will cover the following topics, in roughly this order:

1. DSP REVIEW: linear time-invariant systems, sampling, Fourier analysis, the DFT. Proakis Chapter 1, plus supplemental material on Fourier analysis. 1 week.
2. ALGORITHMS FOR CONVOLUTION AND THE DFT: short algorithms, the Chinese Remainder Theorem, split-radix and number-theoretic transforms. Proakis Chapter 2, plus supplemental material from Blahut. 1.5 weeks.
3. LINEAR PREDICTION AND OPTIMUM LINEAR FILTERS: forward and backward linear prediction, Levinson-Durbin algorithm, AR and ARMA processes, Wiener filters. Proakis Chapter 3, plus supplemental material from Haykin. 1.5 weeks.
4. LEAST-SQUARES AND NUMERICAL METHODS: general least-squares estimation problems, advanced linear algebra, FIR and IIR filter design, quantizer design, recursive least squares. Proakis Chapters 4 and 6, plus supplemental material from Parks and Burrus. 2 weeks.
5. ADAPTIVE FILTERS: applications and the LMS algorithm. Proakis Chapter 5, plus supplemental material from Haykin. 1 week.
6. POWER SPECTRUM ESTIMATION: parametric and nonparametric methods for power spectrum estimation, Yule-Walker equations, model order selection, MUSIC and ESPRIT algorithms. Proakis Chapter 8, plus supplemental material from Haykin. 1.5 weeks.
7. FILTER BANKS: Unitary, linear phase, and perfect-reconstruction filter banks. Relationship to the DFT and DWT. Burrus Chapters 3, 8, and 9, plus supplemental material from Strang. 1 week.
8. WAVELETS: Definition and applications of wavelets, multiresolution analysis, scaling functions and wavelet expansions, wavelet design, biorthogonal wavelets. Burrus Chapters 1, 2, 4, 5, 6, 7, and 10. 3 weeks.

NOTES: There are no RPI classes scheduled on September 2, October 14, and November 27–29. Additionally, I will be at conferences September 23–25 (IEEE ICIP) and December 2–6 (ACM Multimedia - tentative). However, remember that since the oral project presentations are scheduled as a final exam, *you should not plan to leave for winter break any sooner than the last day of final exams! No exceptions!*

CRIMES AND MISDEMEANORS: You are expected to communicate to the instructor any issue regarding your performance in class ahead of time. This includes absence from important class meetings, late assignments, inability to perform an assigned task, problems with your group members, the need for extra time on assignments, etc. You should be prepared to provide sufficient proof of any circumstances on which you are making a special request as outlined in the Rensselaer Handbook of Student Rights and Responsibilities.

Students with disabilities should inform the instructor of their needs at the beginning of the semester. Students must register as disabled in order to receive proper attention and benefits. Please contact Debra Hamilton (Assistant Dean of Students, ext. 2746, hamild@rpi.edu). Students who cannot attend some classes due to religious observance should inform the instructor at the beginning of the semester.

Cheating and academic dishonesty will not be tolerated. All your course work should provide an honest effort in solving the assigned problem by yourself and your group partners. You are encouraged to discuss course material and problems with other students, but your group's solution must be your own, with no copying or sharing of code. If you are inspired by another work, or if you are extending an existing approach, you should explicitly cite this work. Any student found to have participated in academic dishonesty will receive an "F" in the class, and may be subject to further disciplinary action. The University Code of Academic Integrity prohibits students from committing the following acts of academic dishonesty: academic fraud (e.g. changing solutions to appeal a grade), copying or allowing one's work to be copied, collaboration (e.g. giving out old project reports for others to reuse), fabrication/falsification, plagiarism, sabotage of others' work, substitution (e.g. doing a project for someone else). For more details, see <http://www.pde.rpi.edu/academics/policies/dishonesty.shtml>.

Letter grades will not be assigned until the end of the class, after the final project has been graded. Any letter grade assignment posted before the end of the class should be regarded as tentative and subject to change. For grade appeals procedures, see <http://www.pde.rpi.edu/academics/policies/appeals.shtml>.